Information Circular 9446

Proceedings: New Technology for Ground Control in Retreat Mining

Christopher Mark, Ph.D., and Robert J. Tuchman

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Pittsburgh, PA and Spokane, WA Research Centers

March 1997

International Standard Serial Number
ISSN 1066-5552

CONTENTS

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	lbf	pound (force)
ft	foot	m	meter
ft/min	foot per minute	m/min	meter per minute
ft^2	square foot	m^2	square meter
ft^3	cubic foot	m^3	cubic meter
GPa	gigapascal	min	minute
ha	hectare	mm	millimeter
in	inch	MPa	megapascal
in^2	square inch	psi	pound (force) per square inch
kg	kilogram	st	short ton
kips/in	kips per inch	st/h	short ton per hour
kN	kilonewton	t	ton (metric)
kN/cm	kilonewton per centimeter	%	percent
kPa	kilopascal	°	degree
lb	pound		

Mention of any company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

To receive other information about occupational safety and health problems, call
1-800-35-NIOSH (1-800-356-4674), or
visit the NIOSH Home Page on the World Wide Web at
http://www.cdc.gov/niosh/homepage.html

DISCLAIMER OF LIABILITY

The National Institute for Occupational Safety and Health expressly declares that there are no warranties, express or implied, that apply to the software described herein. By acceptance and use of said software, which is conveyed to the user without consideration by the National Institute for Occupational Safety and Health, the user hereof expressly waives any and all claims for damage and/or suits for or by reason of personal injury or property damage, including special, consequential, or other similar damages arising out of or in any way connected with the use of the software described herein.

PROCEEDINGS: NEW TECHNOLOGY FOR GROUND CONTROL IN RETREAT MINING

Compiled by Christopher Mark, Ph.D.,[1] and Robert J. Tuchman[2]

ABSTRACT

This proceedings volume contains papers presented at technology transfer seminars sponsored by the National Institute for Occupational Safety and Health (NIOSH) on New Technology for Ground Control in Retreat Mining. The seminars were conducted at five locations: Uniontown, PA (March 26, 1997), Norton, VA (April 8, 1997), Pikeville, KY (April 10, 1997), Charleston, WV (April 17, 1997), and Evansville, IN (April 22, 1997).

The papers presented here describe several new, highly practical technologies developed by the NIOSH Pittsburgh and Spokane Research Centers[3] to improve safety during pillar retreat operations. Two central issues are addressed: pillar design and mobile roof supports (MRS's).

Proper pillar sizing is essential for safe pillar extraction. The Analysis of Retreat Mining Pillar Stability (ARMPS) program and its large data base of actual mining case histories are presented. LAMODEL, a second computer program, can be used for analysis of multiple-seam and other complex mining situations. Other papers address pillar design to avoid massive pillar collapses and the proper role of coal strength testing.

MRS's have greatly improved safety where they are used for pillar line support. We studied the application of MRS's at 20 mines throughout the Eastern United States. Conclusions regarding the most effective section layouts, cut sequences, and support placements are reported. Field and laboratory tests of MRS's are also described.

---

[1]Mining engineer.

[2]Technical writer-editor.

Pittsburgh Research Center, National Institute for Occupational Safety and Health, Pittsburgh, PA.

[3]The research described in these papers originated under the former U.S. Bureau of Mines prior to transferring to the National Institute for Occupational Safety and Health in 1996.

A STATISTICAL OVERVIEW OF RETREAT MINING OF COAL PILLARS IN THE UNITED STATES

By Christopher Mark, Ph.D.,[1] Frank E. McCall,[1] and Deno M. Pappas[2]

ABSTRACT

The demographics and safety record of the pillar retreat segment of the U.S. coal industry was analyzed using statistics collected by the Mine Safety and Health Administration. Pillar recovery is practiced primarily by mines in Appalachia and the Midwest. Using 1993 data, the accident rates and productivity of a large sample of pillar retreat mines were found to be similar to other room-and-pillar mines in the same geographic areas. Pillar recovery apparently accounts for about 10% of all U.S. underground production, but has been associated with about 25% of the roof and rib fatalities during 1989-96. However, of the 28 fatalities that were analyzed, only 4 occurred for which no citations were issued for violations of mining law. Nearly one-half of the fatal incidents occurred during the mining of the last lift or pushout. All four no-citation incidents occurred during the removal of the last lift during a "Christmas tree" extraction sequence.

[1]Mining engineer.
[2]Civil engineer.
Pittsburgh Research Center, National Institute for Occupational Safety and Health, Pittsburgh, PA.

INTRODUCTION

Pillar recovery has always been an integral part of U.S. underground coal mining. It can be a less capital-intensive, more flexible alternative to longwall mining for small, irregular reserves [Blaiklock 1992]. It is often employed in deeper, high-value seams where recovery rates would be unacceptably low if only development room-and-pillar mining was conducted.

The process of pillar recovery removes the main support to the overburden and allows the ground to cave. As a result, the pillar line is an extremely complex and high-stress rock mechanics environment. Historically, retreat mining has accounted for a large number of fatal roof fall accidents. During 1978-86, 67 roof fall fatalities were attributed to retreat mining, representing 29% of the total. Of the pillaring fatalities, 49% occurred during the mining of the final stump [Montague 1988]. Nevertheless, there has apparently never been a detailed study of the demographics and safety record of pillar retreat mining. This study attempts to fill the gap.

The overview presented here is based almost entirely on information collected by the Mine Safety and Health Administration (MSHA). Three primary sources were used:

• *MSHA Accident and Employment Data Base:* This data base contains information on the employment and production of all U.S. operating coal mines. It also contains information on all accidents reported to MSHA.

• *Data Base of Retreat Mines:* In 1993, MSHA formed the Mine Ventilation Bleeder and Gob Training Committee. Part of the committee's work was to survey the nine bituminous coal MSHA health and safety districts about the practices of their mines. The survey identified 186 nonlongwall mines that were maintaining an active gob and that produced more than 4,500 t (5,000 st) in 1993 [Urosek et al. 1995]. These mines were approximately evenly divided between those that practiced full-pillar recovery and those that were limited to partial pillar extraction. An additional 181 mines had ventilated, inactive gobs. Some had permanently ceased retreat mining, others were developing for pillar recovery operations when they were surveyed. Therefore, the 186 active gob mines represent a large sample of the total retreat mine population. The identification numbers of these mines were the key to making comparisons using the MSHA Accident and Employment Data Base.

• *Fatal Accident Reports:* Since 1988, a total of 25 accidents resulting in 33 fatalities have occurred during pillar recovery operations. MSHA prepared detailed Reports of Investigation on all but the most recent of these fatal incidents, and the reports were subjected to in-depth analyses.

DEMOGRAPHICS AND ACCIDENT RATES

Table 1 compares basic statistics for 1993 for three segments of the U.S. underground coal industry: (1) longwall mines, (2) all room-and-pillar mines, and (3) the sample of 186 room-and-pillar retreat mines.

Table 1 and figures 1-2 show that the sample of retreat mines employed 9,129 miners and produced 56 million t (61.7 million st) in 1993, representing 18% of the total underground production. The 56 million t (61.7 million st) includes both

Table 1.— Demographics and accident statistics for U.S. underground coal mines by mine type[1]

Mine type	No. of mines	No. of employees	Average mine size (employees)	Tons, thousand st	Productivity, st/h	Total accident rate [2]	Roof/rib accident rate [2]	Total days lost rate [3]	Roof/rib days lost rate [3]
Room-and-pillar [4] ...	1,014	33,073	33	214,299	3.45	15.92	1.44	451	41
Retreat [5]	186	9,129	49	61,701	3.27	15.58	1.14	432	29
Longwall	69	15,419	223	133,132	4.16	13.39	1.00	410	29
Entire industry	1,083	48,491	45	347,430	3.69	15.06	1.29	437	37

[1]Excludes anthracite mines and mines producing less than 5,000 st.
[2]Accident rates are calculated as the total number of injury accidents (severity 1-6) per 200,000 hours worked.
[3]Days lost rates are calculated as the total number of days lost due to injury per 200,000 hours worked.
[4]Room-and-pillar mines include all nonlongwall mines.
[5]Retreat mines are the 186 nonlongwall mines with active gobs identified by Urosek et al. [1995].

Source: MSHA Accident and Employment Data Base for 1993.

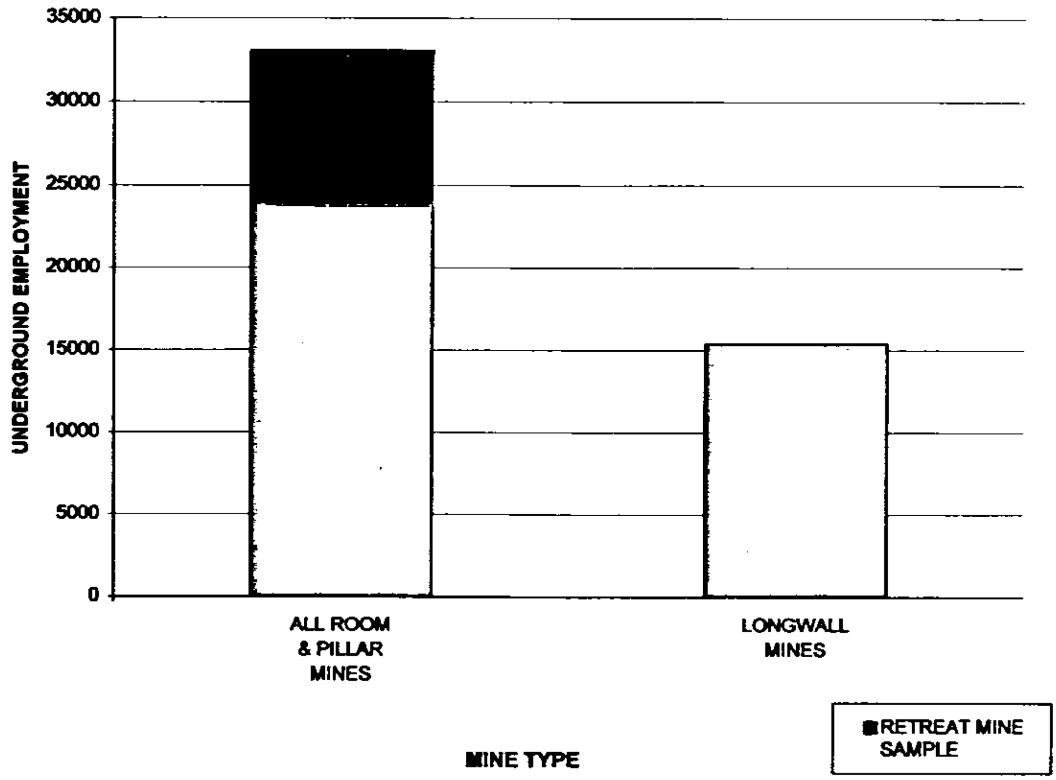

Figure 1.—Employment at U.S. underground coal mines in 1993, by mine type.

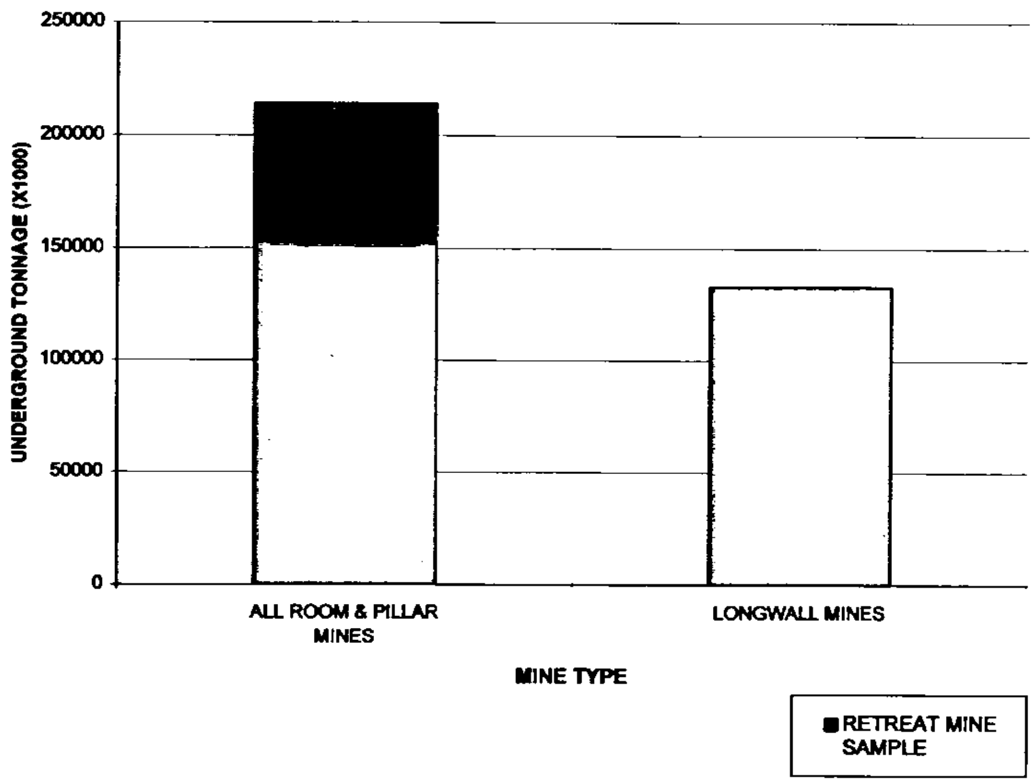

Figure 2.—Production at U.S. underground coal mines in 1993, by mine type.

development and retreat tonnage. A reasonable estimate is that pillar recovery operations account for about one-third of coal production from retreat mines [Reese et al. 1978]. Including some contribution from the mines with inactive ventilated gobs, it appears that pillar recovery may have accounted for about 10% of the 315 million t (347 million st) mined underground in 1993.

An average of 49 miners were employed at each pillar retreat mine, slightly more than at the typical room-and-pillar mine, but much less than at a longwall mine. The accident statistics in figure 3 show that, overall, the injury record of retreat mines was similar to that of other mining methods. Surprisingly, roof and rib accident rates in figure 4 were 21% *lower* at retreat mines than at other room-and-pillar mines. One possible explanation is that roof bolting, which is a significant source of roof fall injuries, is seldom employed during retreat mining. The rates for days lost from all accidents closely paralleled the overall accident rates.

Some regional trends are shown in table 2 and figures 5-6. It appears that retreat mining was widely practiced throughout the Appalachian and midwestern U.S. coal mining areas. The only MSHA districts with few active pillar recovery operations were District 3 (northern West Virginia), District 9 (primarily Colorado, Wyoming, and Utah), and District 10 (western Kentucky).

The largest number of retreat mines were found in the southern Appalachian coalfields (MSHA District 4 in southern West Virginia; District 5 in Virginia; District 6 in eastern Kentucky; and District 7 in eastern Kentucky and Alabama). These four MSHA districts accounted for 156 mines, or 85% of the sample. The retreat mines in this region were typically smaller than those in other districts, averaging 40 employees each, compared with 83 in the average mine outside the region.

Accident rates vary from MSHA district to district, as shown in figure 7. Within each district, they tend to be similar between the retreat mine sample and all room-and-pillar mines. Roof and rib accident rates were lower in 1993 at the retreat mines in six of the eight districts.

Table 3 and figure 8 show that retreat mines tended to be larger than the average room-and-pillar mines. Only 15% of all small mines were conducting active pillar recovery operations, whereas about 40% of all medium and large mines were recovering pillars.[3] Accident rates did not show any significant trends with regard to mine size.

[3]Small mines are those employing fewer than 50 workers; medium mines employ 50 to 150 workers; large mines employ more than 150 workers.

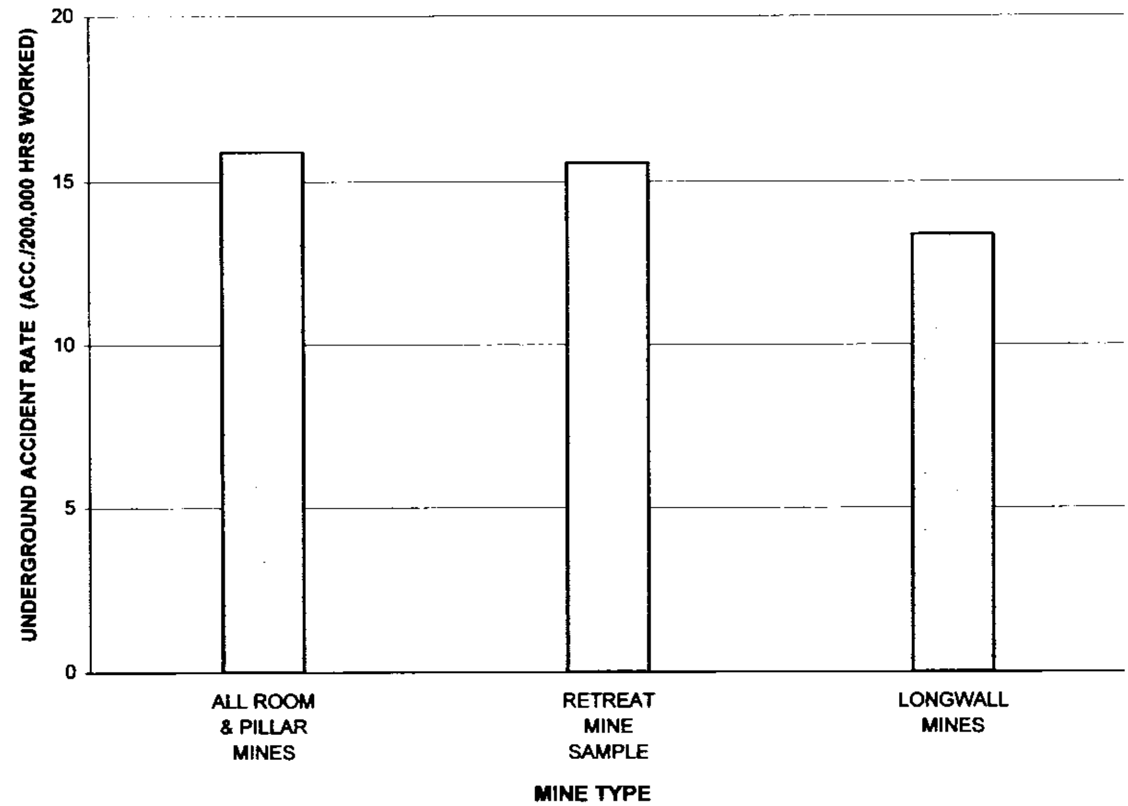

Figure 3.—Accident rate at U.S. underground coal mines in 1993, by mine type.

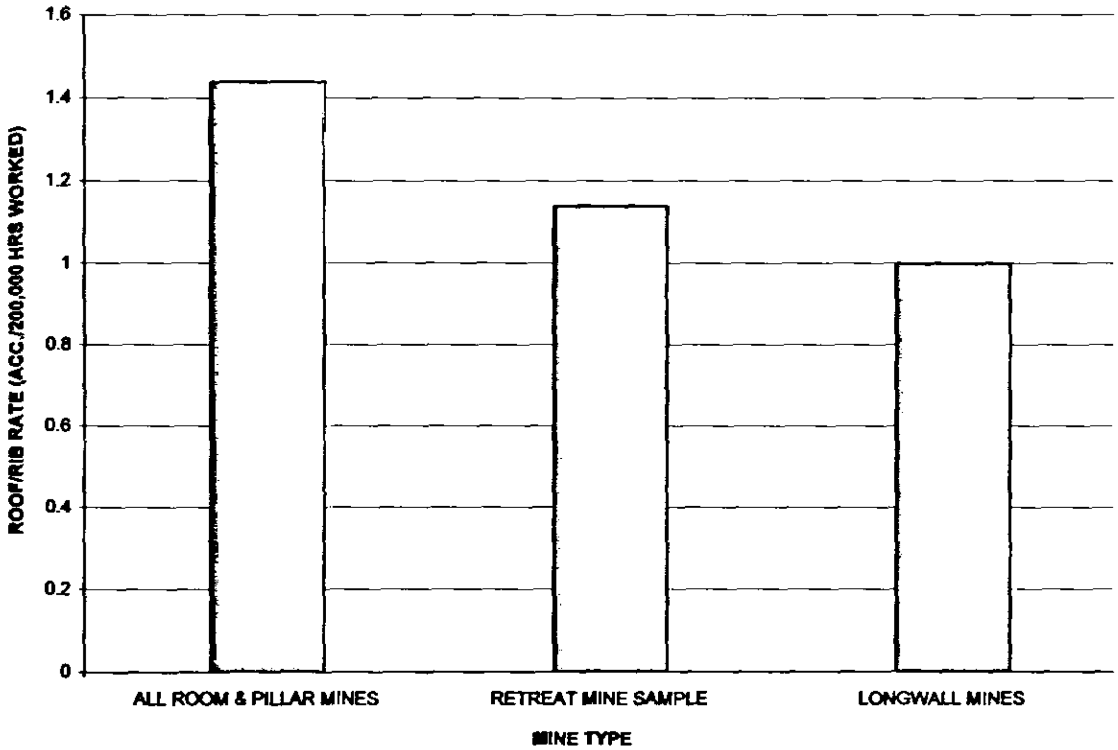

Figure 4.—Roof/rib accident rates at U.S. underground coal mines in 1993, by mine type.

Table 2.—Demographics and accident statistics for U.S. underground coal mines by MSHA district[1]

MSHA District No.	No. of mines	No. of employees	Average mine size (employees)	Tons, thousand st	Productivity, st/h	Total accident rate [2]	Roof/rib accident rate [2]	Total days lost rate [3]	Roof/rib days lost rate [3]
				RETREAT [4]					
2	13	1,029	79	4,495	2.10	27.40	1.31	942	24
3	7	240	34	1,702	3.46	10.15	0.41	145	11
4	57	2,184	38	15,260	3.60	15.91	1.37	592	47
5	37	1,215	33	7,504	2.91	11.64	0.78	230	13
6	28	948	34	7,525	3.74	15.22	1.49	302	21
7	34	1,878	55	12,069	2.99	13.31	0.84	271	15
8	8	1,323	165	9,755	3.64	16.48	1.42	387	38
9	7	314	45	3,388	4.83	6.56	0.86	330	78
10	0	0	0	0	0	0	0	0	0
				ROOM-AND-PILLAR [5]					
2	52	2,122	41	11,134	2.66	26.34	1.15	785	31
3	60	1,720	29	11,093	3.38	11.50	0.85	306	33
4	256	7,490	29	49,797	3.80	16.31	1.64	564	56
5	164	4,090	25	21,465	2.82	12.97	1.24	456	37
6	228	5,447	24	34,356	3.65	16.42	1.82	400	50
7	192	6,069	32	37,087	3.08	14.34	1.11	309	20
8	23	3,443	150	25,435	3.75	17.27	1.41	466	37
9	20	836	42	8,061	4.37	10.30	1.08	317	36
10	19	1,856	98	15,685	4.07	16.88	2.29	413	65

[1]Excludes anthracite mines and mines producing less than 5,000 st.
[2]Accident rates are calculated as the total number of injury accidents (severity 1-6) per 200,000 hours worked.
[3]Days lost rates are calculated as the total number of days lost due to injury per 200,000 hours worked.
[4]Retreat mines are the 186 nonlongwall mines with active gobs identified by Urosek et al. [1995].
[5]Room-and-pillar mines include all nonlongwall mines.

Source: MSHA Accident and Employment Data Base for 1993.

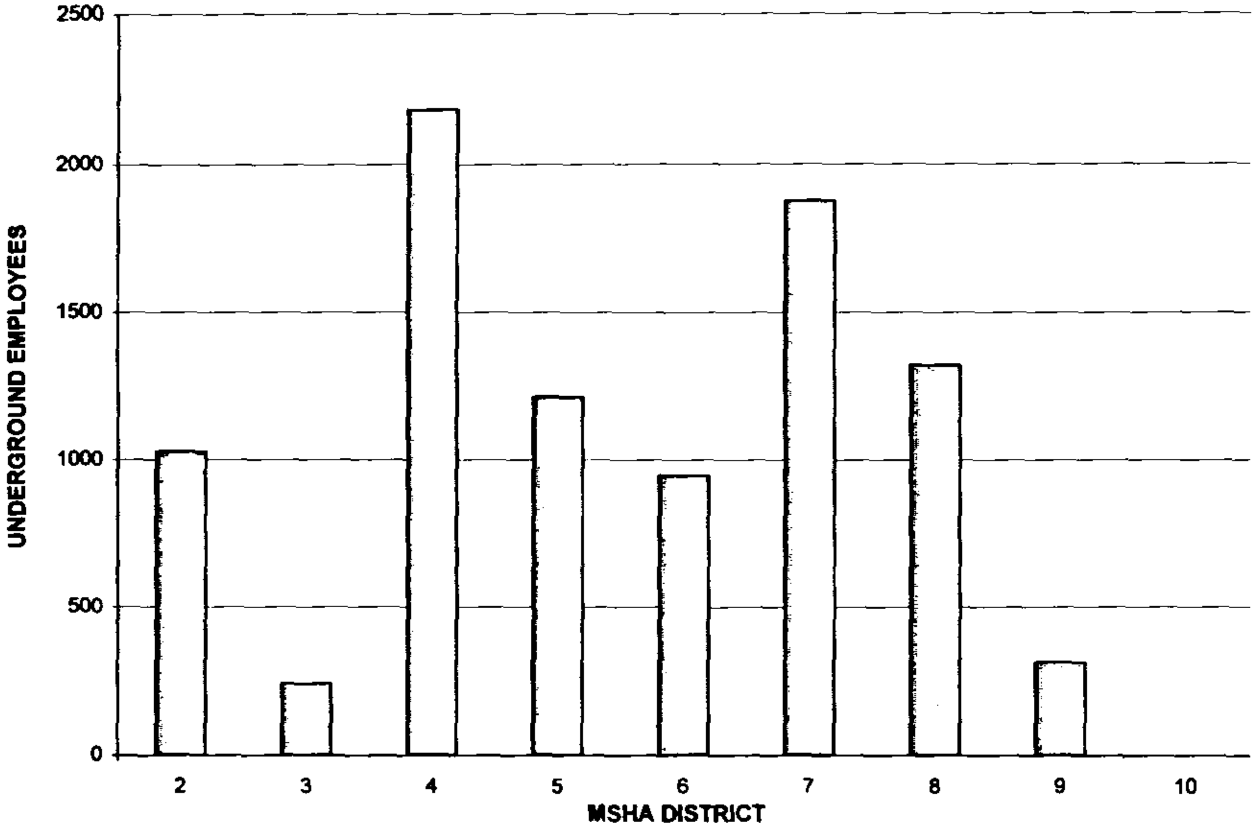

Figure 5.—Employment at sample retreat mines, by MSHA district.

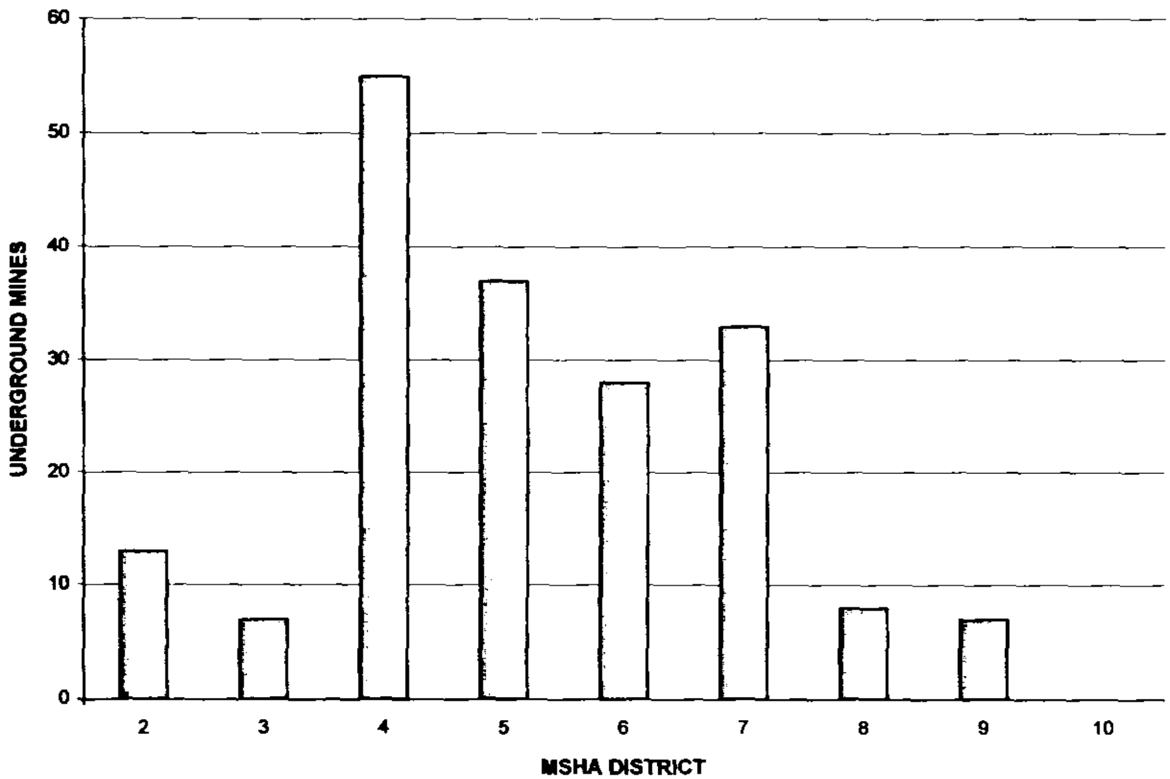

Figure 6.—Number of sample retreat mines, by MSHA district.

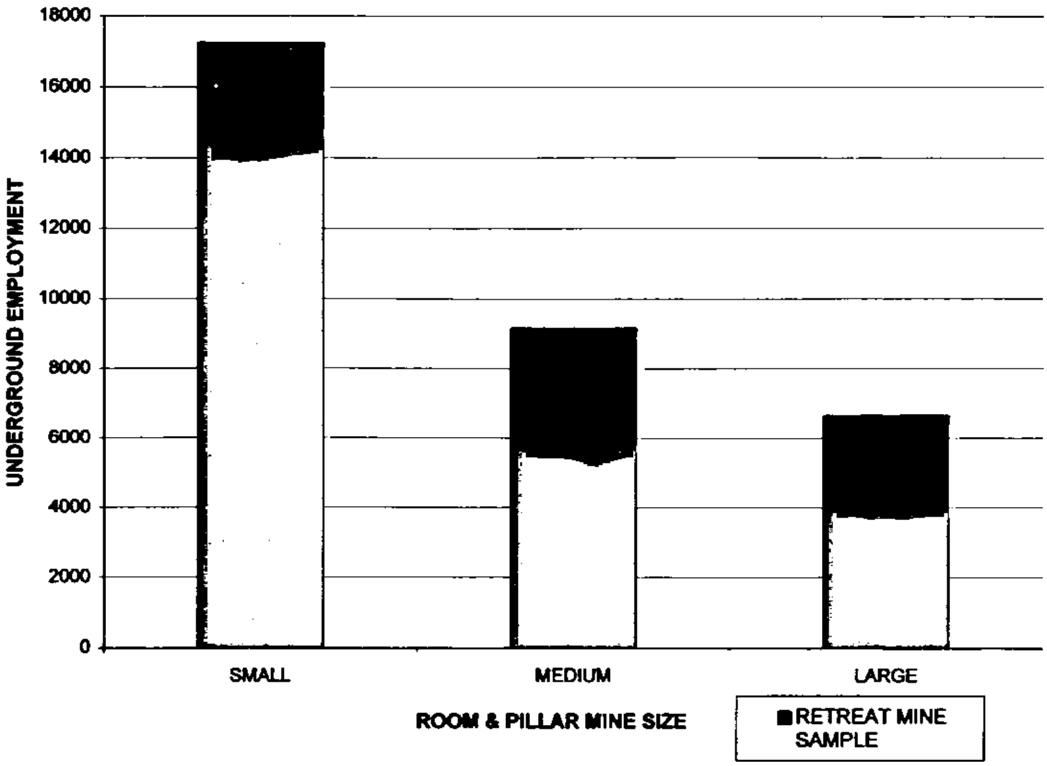

Figure 7.—Employment at retreat and all room-and-pillar mines, by mine size.

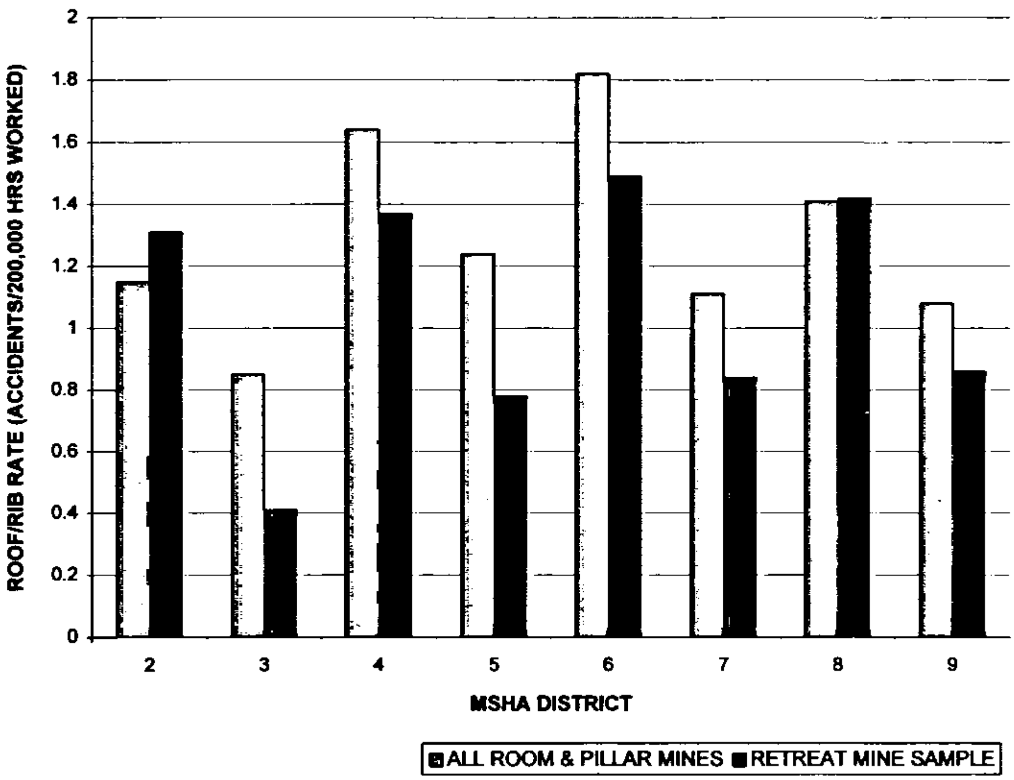

Figure 8.—Roof/rib accident rates at retreat and all room-and pillar mines, by MSHA district.

Table 3.—Demographics and accident statistics for U.S. underground coal mines by mine size[1]

Mine size	No. of mines	No. of employees	Average mine size (employees)	Tons, thousand st	Productivity, st/h	Total accident rate [2]	Roof/rib accident rate [2]	Total days lost rate [3]	Roof/rib days lost rate [3]
RETREAT [4]									
Small [5]	133	2,892	22	20,376	3.50	13.18	1.20	305	27
Medium [6]	41	3,481	85	23,785	3.25	17.30	1.04	466	26
Large [7]	12	2,756	230	17,539	3.06	15.83	1.22	519	35
ROOM-AND-PILLAR [8]									
Small [5]	873	17,253	20	103,912	3.50	14.76	1.44	353	37
Medium [6]	113	9,166	81	67,299	3.57	17.07	1.45	541	46
Large [7]	28	6,653	238	43,087	3.17	16.84	1.43	539	41

[1]Excludes anthracite mines and mines producing less than 5,000 st.
[2]Accident rates are calculated as the total number of injury accidents (severity 1-6) per 200,000 hours worked.
[3]Days lost rates are calculated as the total number of days lost due to injury per 200,000 hours worked.
[4]Retreat mines are the 186 nonlongwall mines with active gobs identified by Urosek et al. [1995].
[5]Small mines are those employing fewer than 50 workers.
[6]Medium mines are those employing 50 to 150 workers
[7]Large mines are those employing more than 150 workers.
[8]Room-and-pillar mines include all nonlongwall mines.

ANALYSIS OF FATAL INCIDENTS

A total of 25 fatal incidents, resulting in 33 deaths, have been attributed to retreat mining during 1989-96. These fatalities represent 25% of the 111 roof and rib fatalities that occurred during this period (figure 9). Four of the retreat mining fatal incidents (comprising five fatalities) occurred during room development with no apparent influence of a gob. A report by MSHA has not been completed on the most recent incident, a double fatality in Kentucky. The appendix to this paper summarizes the information collected on the 20 fatal incidents available for analysis.

Figure 10 shows that, in four incidents, no citations were issued for violations of mining law or the mine's roof control plan. The remaining 16 fatal incidents were divided into 2 categories, or classes. Class 1 includes eight incidents where gross violation of mining law (and often common sense) was deemed to be the chief factor. Class 2 incidents were those where a violation contributed to the fatality, but where other factors appeared to have played an important role as well. Class 3 incidents were those for which no citations were issued.

Figure 11 shows that the States of Kentucky, Tennessee, and West Virginia have accounted for 92% of all pillaring fatalities. Every incident in Kentucky and Tennessee involved a violation. All four of the no-citation incidents occurred in West Virginia.

Geologic factors were cited in eight instances as contributing to the fatal incidents. Roof slips and slickensides were the most common features. The no-citation incidents involved a first fall, a geologic feature, and a multiple-seam interaction (figure 12). High vertical stress was a factor in three of the class 2 fatal incidents. The types of violations cited in the other incidents are shown in figure 13. Mining sequence violations were most frequently cited in the class 2 fatal incidents.

The mining techniques employed to extract pillars are shown in figure 14. All five fatalities during slabbing operations occurred on conventional mining sections. Partial pillaring or "Christmas tree" methods were used in 82% of the incidents where continuous miners were employed.

In 45% of the fatal incidents, the pushout or last lift was being extracted at the time of the fall (figure 15). All four of the no-citation fatal incidents had two significant factors in common. All employed the Christmas tree extraction sequence, and in every case the continuous miner was extracting the last lift.

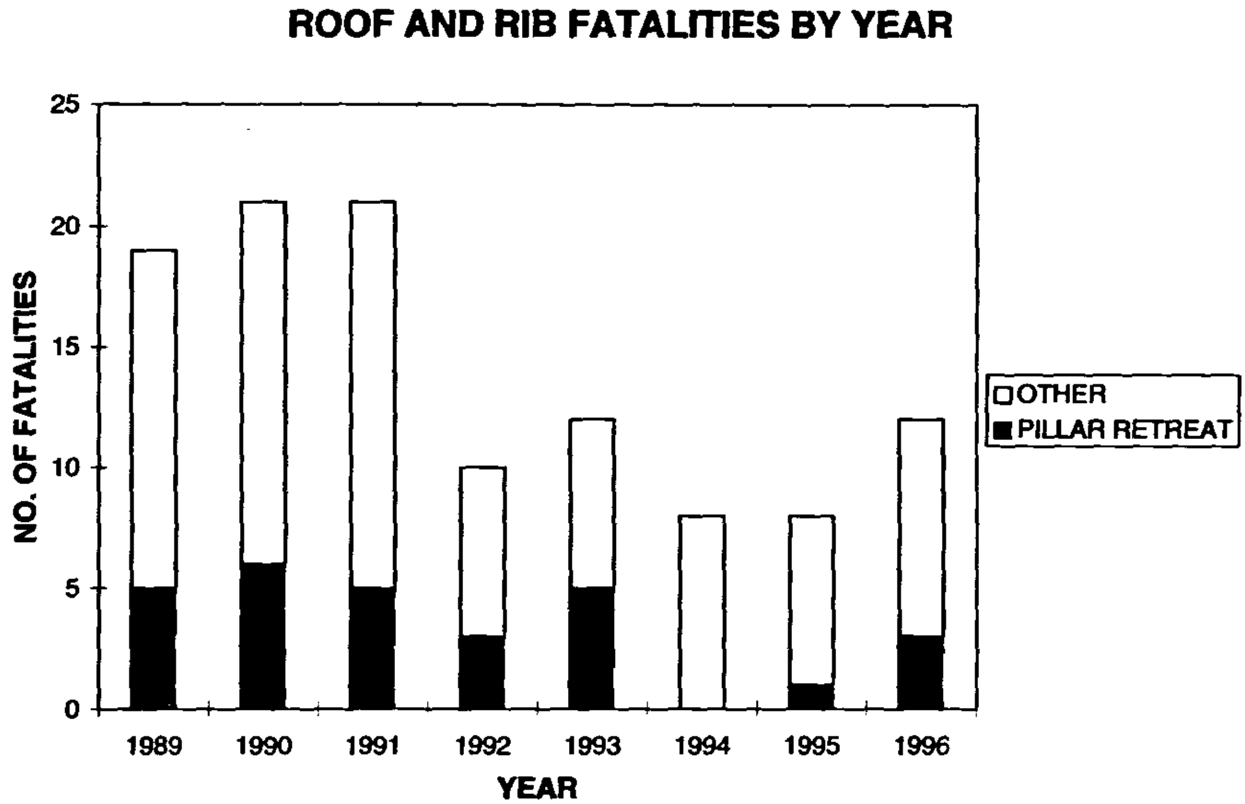

Figure 9.—Roof/rib fatalities, 1989-96.

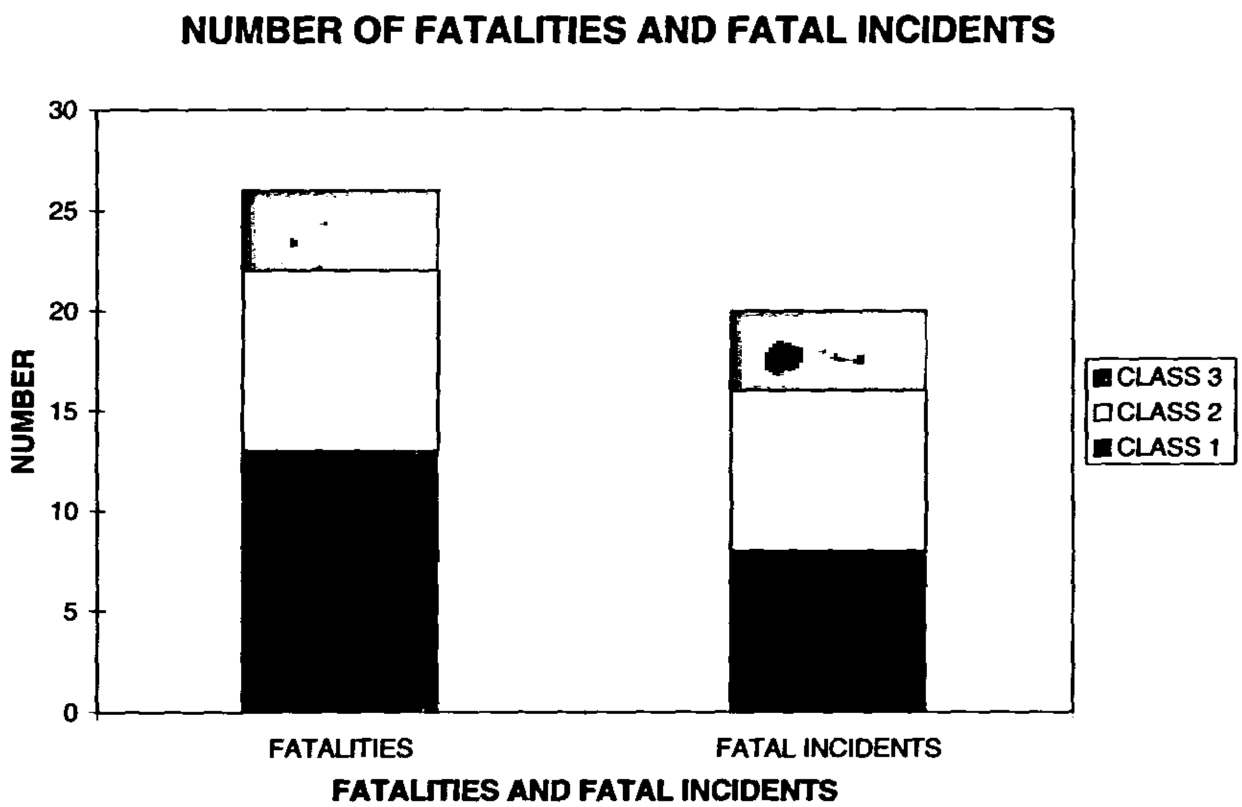

Figure 10.—Fatal roof/rib incidents and fatalities associated with retreat mining, 1989-96.

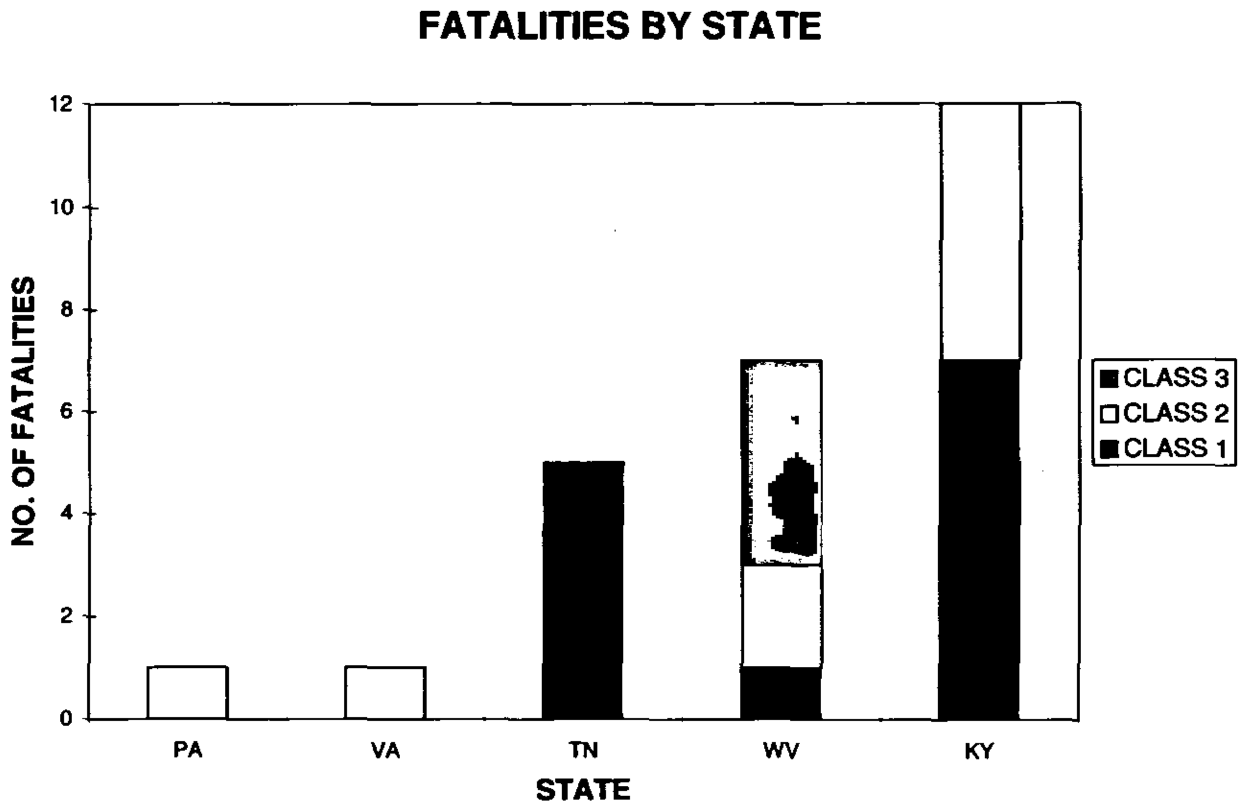

Figure 11.—Retreat mining fatal incidents, by State.

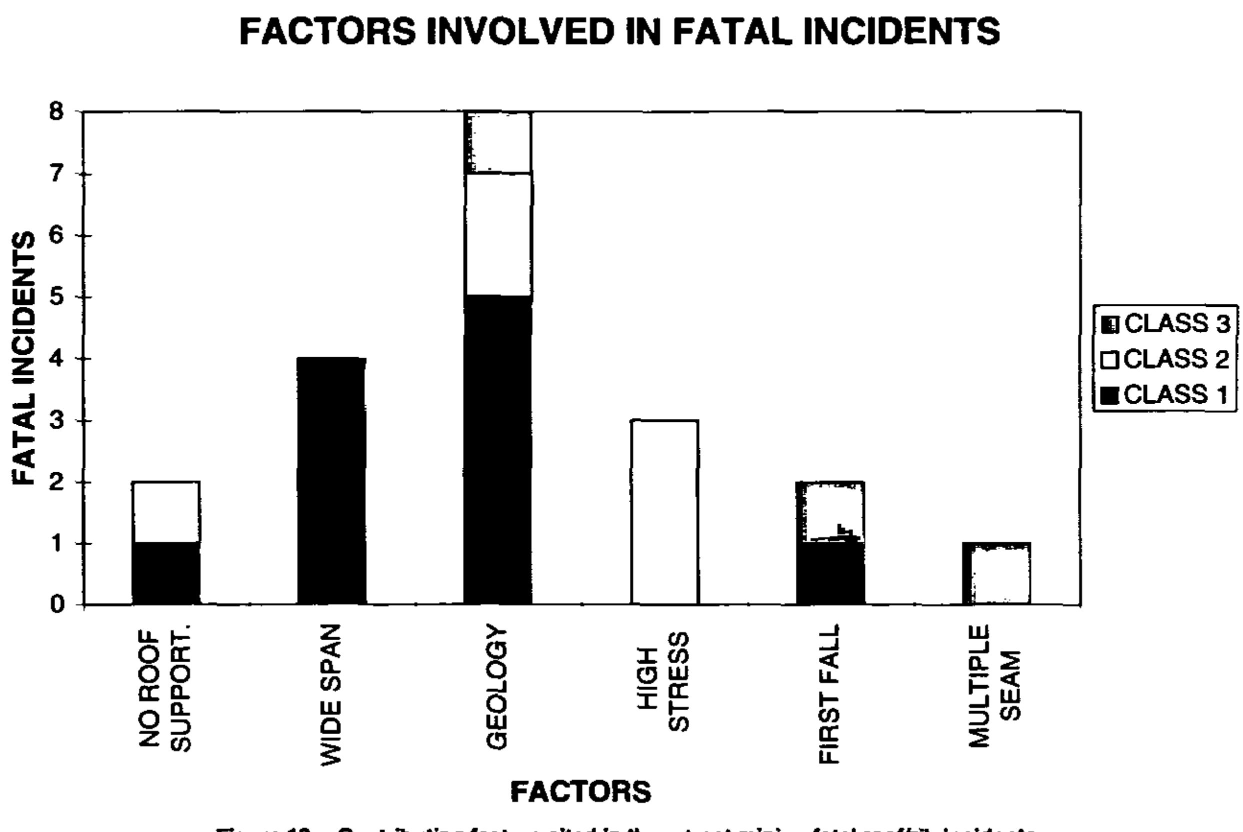

Figure 12.—Contributing factors cited in the retreat mining fatal roof/rib incidents.

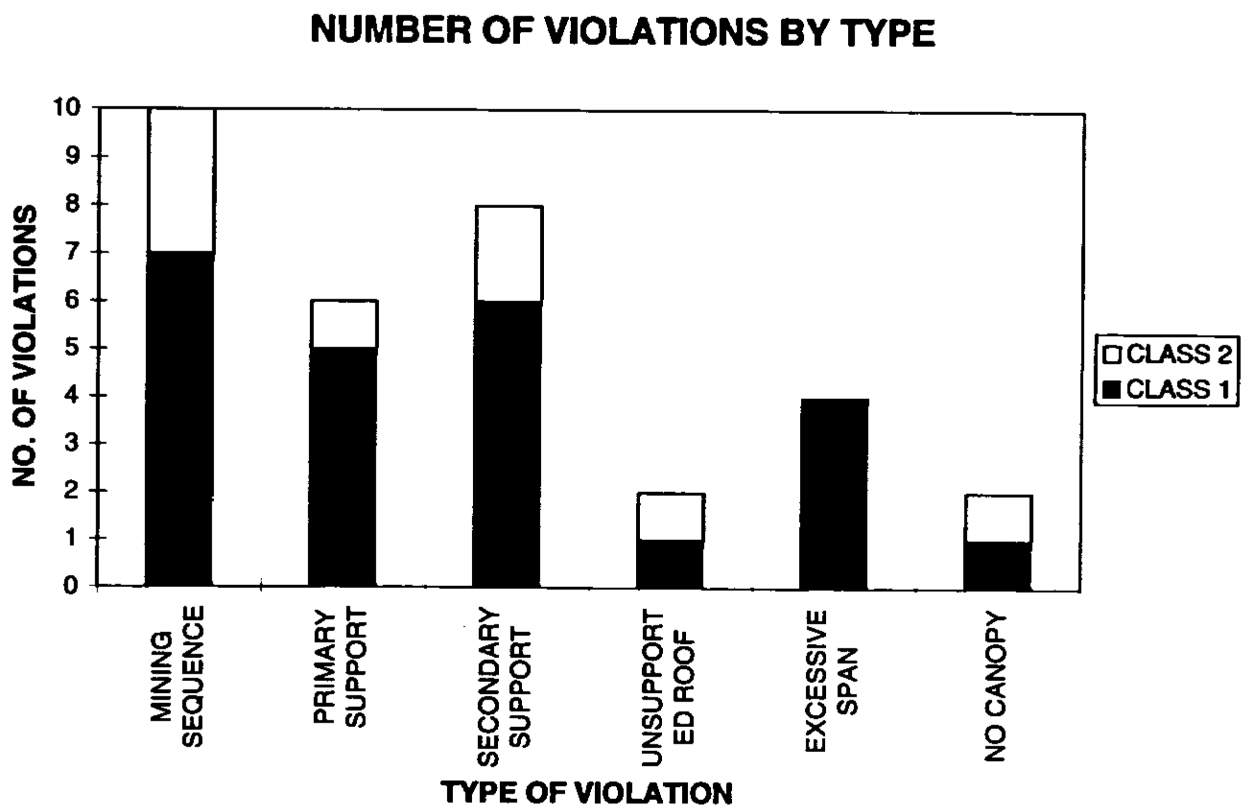

Figure 13.—Types of violations cited in the retreat mining fatal roof/rib incidents.

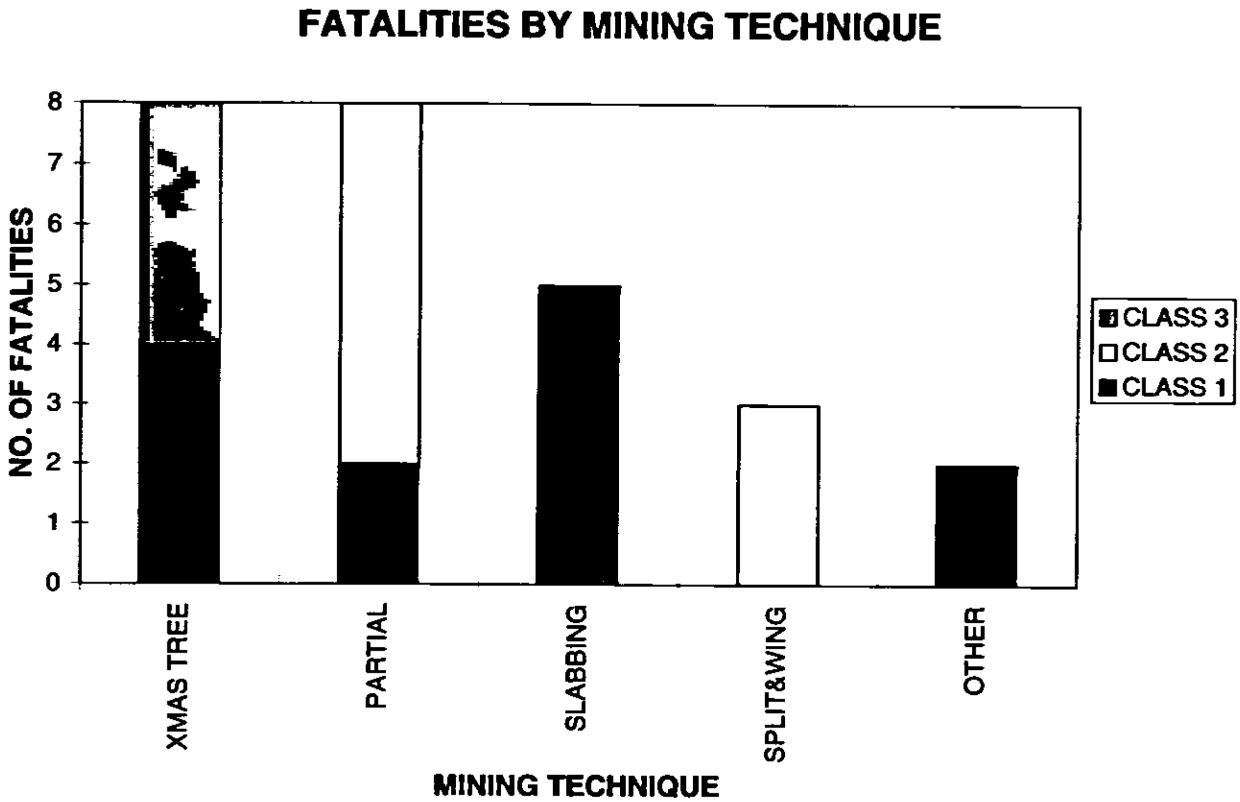

Figure 14.—Pillar extraction techniques employed in the retreat mining fatal roof/rib incidents.

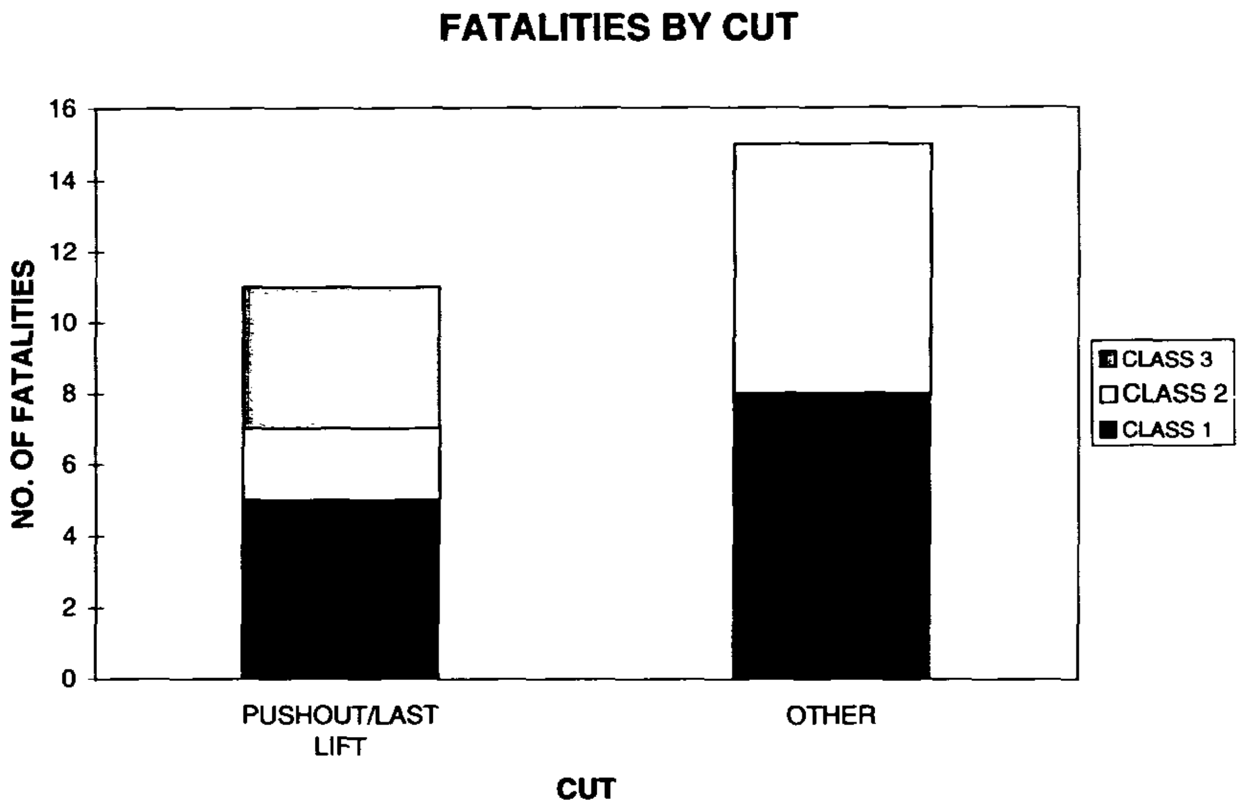

Figure 15.—Lift being extracted when fatal roof fall occurred.

CONCLUSIONS

Pillar recovery is employed in many U.S. coal regions. It is practiced primarily at many medium and some small mines. The overall accident rates for retreat mines appear to be similar to those of other room-and-pillar mines. The number of fatalities that have occurred during pillar recovery operations seems disproportionately high relative to coal production. Many fatalities that have occurred during retreat operations can be largely attributed to violations of existing mining law. Nearly 50% of fatal incidents have occurred during the recovery of the final lift (or pushout). Other potential problem areas include high stress/deep cover, first falls, geologic factors, mining sequence, and multiple-seam interactions.

REFERENCES

Blaiklock J [1992]. A Kentuckian vote for continuous mining. Mining Magazine *June*:365-366.

Montague PG [1988]. Pillar recovery—the lost art? In: Proceedings of the American Mining Congress. Chicago, IL: pp. 531-548.

Reese RG, Dash BB, Hamilton PA [1978]. Coal recovery from underground bituminous coal mines in the United States, by mining method. Washington, DC: U.S. Department of the Interior, Bureau of Mines, IC 8785.

Urosek JE, Zuchelli DR, Beiter DA [1995]. Gob ventilation and bleeder systems in U.S. coal mines. Soc Min Eng preprint 95-78.

APPENDIX.—INFORMATION ON FATAL PILLAR RECOVERY INCIDENTS

Table A-1.—Information on fatal pillar recovery incidents (from MSHA Reports of Investigation)

Year, State, and seam	Extraction technique	Equipment	Seam height, in	Roof geology	Entry width, ft	Cut	Fatality occupation	Compliance class	Mining sequence violation	Primary support violation	Secondary support violation
1989:											
Kentucky:											
Haddix	Slabbing	Conventional	54	Mod. - weak	17-25	Other	Cut. mach. oper.	1	Yes	Yes	Yes
Upper Hignite	Christmas tree	Cab CM	60	Mod. - weak	20	Pushout	Roof bolters (2), supplyman.	1	No	No	Yes
Virginia:											
Jawbone	Partial	Cab CM	84	Moderate	18-20	Other	Shuttle car oper.	2	No	No	No
1990:											
Kentucky:											
Creech	Other	Remote CM	36	Moderate	—	Pushout	Foreman	1	Yes	No	Yes
High Splint	Split-and-wing	Remote CM	60	Weak	18-19	Pushout	Foreman	2	No	No	Yes
Pond Creek	Partial	Remote CM	50	Weak	18	Other	CM helper	2	Yes	No	No
Pennsylvania:											
Pittsburgh	Split-and-wing	Cab CM	120	Strong	18	Pushout	Roof bolter	2	Yes	No	Yes
Tennessee:											
Jellico	Other	Remote CM	40	Moderate	—	Other	CM operator	1	Yes	Yes	No
West Virginia:											
Middle Kittanning	Split-and-wing	Cab CM	60	Weak	20	Other	Roof bolter	2	No	Yes	No
1991:											
Kentucky:											
Hazard No. 4	Partial	Remote CM	54	Mod. - weak	20	Other	CM operator, CM helper.	1	Yes	Yes	No
Pond Creek	Partial	Remote CM	56	Weak	20	Other	Timber setter	2	Yes	No	No
West Virginia:											
Dorothy	Partial	Remote CM	78	Weak	20	Other	Foreman	2	No	No	No
Hernshaw	Christmas tree	Remote CM	52	Weak	20	Pushout	Foreman	1	Yes	No	Yes
1992:											
Tennessee:											
Sewanee	Slabbing	Conventional	36	Weak	20	Other	Roof bolter, utility man.	1	Yes	Yes	Yes
West Virginia:											
Upper Dorothy	Christmas tree	Cab CM	74	Strong	18	Pushout	Foreman	3	No	No	No
1993:											
Kentucky:											
Hazard No. 4	Partial	Cab CM	44	Mod. - weak	20	Other	Roof bolter, scoop operator.	2	No	No	No
Tennessee:											
Sewanee	Slabbing	Conventional	36	Moderate	—	Other	Foreman, roof bolter.	1	Yes	Yes	Yes
West Virginia:											
Pocahontas No. 3	Christmas tree	Cab CM	60	Weak	20	Pushout	CM helper	3	No	No	No
1995:											
West Virginia:											
Coalburg	Christmas tree	Remote CM	72	Strong	20	Last cut	MRS operator	3	No	No	No
1996:											
West Virginia:											
Beckley	Christmas tree	Remote CM	84	Moderate	20	Pushout	CM operator	3	No	No	No

Table A-1.—Information on fatal pillar recovery incidents (from MSHA Reports of Investigation)—Continued

Year, State, and seam	Victim under unsupported roof	Excessive span	Geological factor	Excessive stress	First fall	Victim location	Saved by canopy	Killed with no canopy	Pillar length, ft	Pillar width, ft
1989:										
Kentucky:										
Haddix	No	Yes	No	No	No	Intersection	No	Yes	35	35
Upper Hignite	No	No	Slickenslided slip	No	No	Intersection	No	No	40	40
Virginia:										
Jawbone	No	No	No	Depth	No	Other	No	Yes	—	—
1990:										
Kentucky:										
Creech	No	No	No	No	Yes	Intersection	No	No	—	—
High Splint	No	No	No	No	No	Intersection	No	No	—	—
Pond Creek	No	No	No	No	No	Other	Yes	No	40	40
Pennsylvania:										
Pittsburgh	No	No	No	No	No	Other	No	No	80	50
Tennessee:										
Jellico	Yes	Yes	No	No	No	Other	No	No	—	—
West Virginia:										
Middle Kittanning	Yes	No	Slickenslided slip	No	No	Other	No	No	45	45
1991:										
Kentucky:										
Hazard No. 4	No	No	Hill seams; shale thickened	No	No	Other	No	No	40	40
Pond Creek	No	No	No	No	No	Intersection	No	No	40	40
West Virginia:										
Dorothy	No	No	Roof fractures (cutters)	Depth	No	Intersection	No	No	55	30
Hernshaw	No	No	Slickenslides	No	No	Other	No	No	50	35
1992:										
Tennessee:										
Sewanee	No	Yes	Slickenslided slip	No	No	Other; intersection	No	No	30	20
West Virginia:										
Upper Dorothy	No	No	No	Multiple seam	No	Intersection	Yes	No	62	32
1993:										
Kentucky:										
Hazard No. 4	No	No	No	Depth	No	Intersection	No	No	30	40
Tennessee:										
Sewanee	No	Yes	Slickenslided slip	No	No	Intersection	No	No	40	40
West Virginia:										
Pocahontas No. 3	No	No	Slickenslided horseback	No	No	Other	Yes	No	50	30
1995:										
West Virginia:										
Coalburg	No	No	No	No	Yes	Other	No	No	40	40
1996:										
West Virginia:										
Beckley	No	No	No	No	No	Intersection	No	No	50	70

Table A-1.—Information on fatal pillar recovery incidents (from MSHA Reports of Investigation)—Continued

Year, State, and seam	Remarks
1989:	
Kentucky:	
Haddix	The cutting machine did not have a protective canopy. Slabbing created a span that was about 30 ft at the accident site.
Upper Hignite	Victims in dangerous location during mining of pushout. No signs of weight on the section. Miner operator was 12 ft inby roof bolts during mining of pillar cuts.
Virginia:	
Jawbone	Rib sloughing caused fatal injuries to the shuttle car operator. The shuttle car did not have a car or canopy, as required when the mining height exceeds 42 in.
1990:	
Kentucky:	
Creech	Visible cracks in the mine roof in the intersection where the accident occurred prior to the day of the accident. Exceeded 20-ft cut by 18 ft at various locations.
High Splint	The victim was in a hazardous position while the continuous miner was being operated. The first pillar fall occurred 45 min before the fall that caused the accident.
PondCreek	Actual mining far exceeded the approval plan. The roof fell 5 to 6 ft to a plane of weakness above the roof line, which was above the anchorage of the 36-in roof bolts.
Pennsylvania:	
Pittsburgh	A sufficient amount of coal was not left in place to adequately support the roof or was not removed to allow the roof to fall in a controlled manner.
Tennessee:	
Jellico	Five employees were positioned 10 to 30 ft inby permanent roof support. Last cut extended 61 ft; only 20 ft was permitted by roof control plan.
West Virginia:	
Middle Kittanning	The canopy over the controls was for another model of roof bolter. No additional support was installed inby the edge of the slip.
1991:	
Kentucky:	
Hazard No. 4	The hill seams were not adequately supported. Not enough coal was left inby the cut in the No. 2 pillar; the cut in the No. 3 pillar was started too close to the corner.
Pond Creek	The cut taken out of the right side of pillar No. 4 measured 23 ft wide and 39 ft deep. The approved roof control plan states that no cut will be more than 20 ft wide and 20 ft deep.
West Virginia:	
Dorothy	Accident area was developed 6 years earlier. A fatality and roof falls occurred previously with this system of mining. MSHA deemed the roof support plan inadequate.
Hernshaw	Approved cut depths were exceeded. Several lifts had been extracted without any supports installed.
1992:	
Tennessee:	
Sewanee	Slabbing created wide unsupported spans. A slickensided slip was not properly supported. Employees routinely traveled inby permanent support when loading.
West Virginia:	
Upper Dorothy	Four coal seams had been mined underneath this mine. There were no violations. The shale below the sandstone concealed the cracks in the overlying sandstone.
1992:	
Kentucky:	
Hazard No. 4	High pressure was evident in the fall location. This resulted from stresses on the active pillar line and an adjacent pillar area. The size of the pillars on the active pillar line was not sufficient to prevent pressure from overriding the pillar line. Due to equipment design and pillar orientation, full and partial extraction were conducted on the same pillar line.
Tennessee:	
Sewanee	Instead of making splits and lifts, slabbing was done. Slabbing created a span of 30 by 50 ft in the intersection where the accident occurred. Turn and roadway posts were not set as required. Loader operator was inby permanent supports when loading lifts.
West Virginia:	
Pocahontas No. 3	There were no violations on the section. A large slickensided horseback fell, causing the accident. The miner operator was saved by a canopy.
1995:	
West Virginia:	
Coalburg	The pressure gauges on the MRS units are small and located in positions requiring operators to stand close to the MRS units to observe the pressure readings. Pillars were being extracted 150 ft from the coal outcrop. The hydraulic gauges took a sudden rise of several hundred pounds immediately before the fall.
1996:	
West Virginia:	
Beckley	Some of the pillars were partially mined; others were fully mined in the same row due to poor roof conditions. There was minor floor heave in the immediate area of the accident, but not elsewhere on the section.